ECL 1-16

Engineering Case Library

SELECTED DESIGN NOTES

LANDING GEAR —
Hydraulic Brake Control Valve

design notes

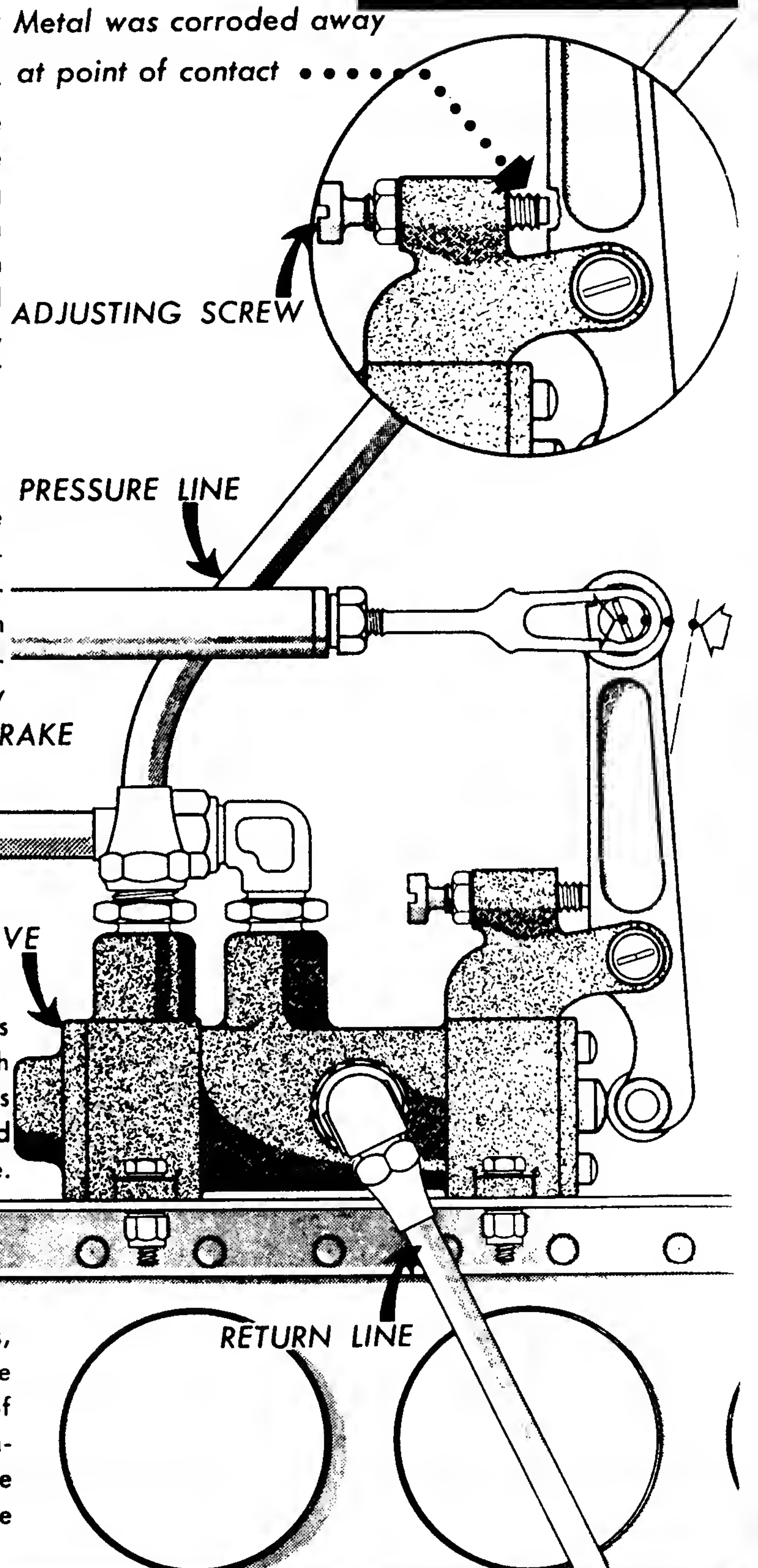
Corrosion Caused Frequent Readjustment of Brake Control System

the Situation

CONSIDERABLE DIFFICULTY was experienced in maintaining proper adjustment of the brake control systems of one type of aircraft used by an airline. The trouble was traced to the hydraulic pressure control valve lever which was made of an aluminum alloy in contact with a steel adjusting screw. The dissimilar metals contacting each other in the presence of moist sea air in some areas in which the aircraft operated, caused the lever to corrode and be rapidly eaten away at the point of contact. Costly, time-consuming replacement of the lever and frequent readjustment of the brake system was necessary.

the Hazard

Inability to maintain the brake control system in the close adjustment required for reliable functioning of this important system might have had serious results if the maintenance technicians had not been alert in discovering this normally unexpected condition.



the Fix

Exposed contacting surfaces should be of similar metals, such as stainless steel, in situations wherein mechanisms are exposed to electrolytic action of salt-laden, moist atmosphere.

PRECEPT

The structure and its components, especially moving parts, should be protected against the effects of environment likely to be encountered in service such as vibration, dust, great pressure differentials, oil mists, corrosion and temperature extremes.

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BULLETIN NO. 55-11

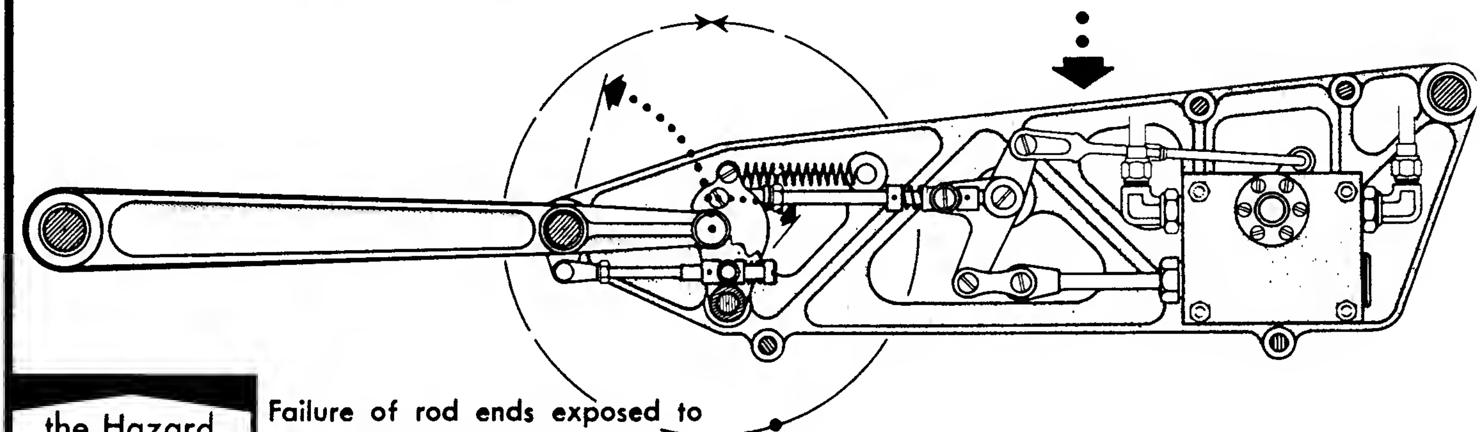
LANDING GEAR — Downlock Actuating Mechanism

design notes

Downlock Failure Caused Unwanted Retraction of Gear

the Situation

CONSIDERABLE DAMAGE to a large transport was inflicted when one of the main landing gear units retracted inadvertantly during the landing roll. Investigation revealed the downlock actuating rod had snapped due to fatigue failure of the threaded portion above the lock nut causing the locking mechanism to remain unlatched.

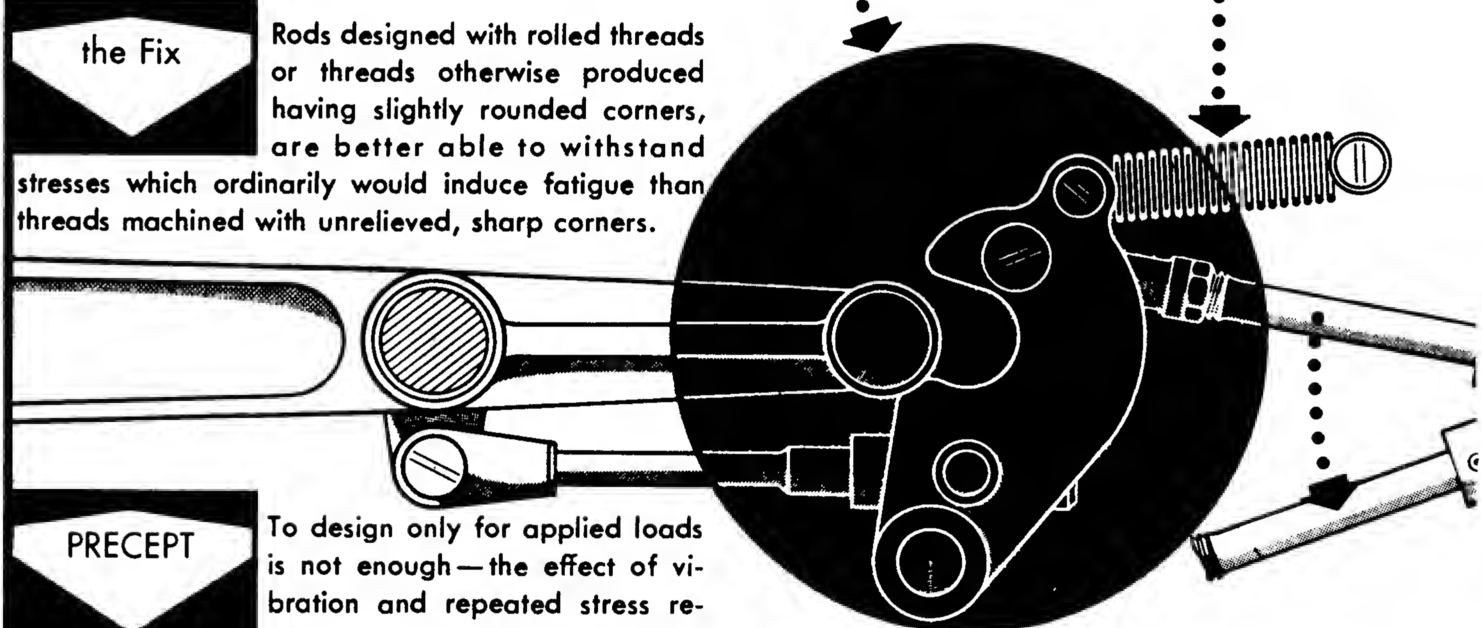


the Hazard

Failure of rod ends exposed to vibration is a frequent occurrence when the length adjusting portions of the rods are designed with sharp V threads being specified. Stress concentrations occur in the sharp corners resulting in eventual fatigue failure if conditions are such as to subject mechanisms to excessive vibration.

the Fix

Rods designed with rolled threads or threads otherwise produced having slightly rounded corners, are better able to withstand stresses which ordinarily would induce fatigue than threads machined with unrelieved, sharp corners.



PRECEPT

To design only for applied loads is not enough — the effect of vibration and repeated stress reversal on parts and assemblies in service must be considered

Ref: *DESIGN NOTES*. Bulletin 55-3

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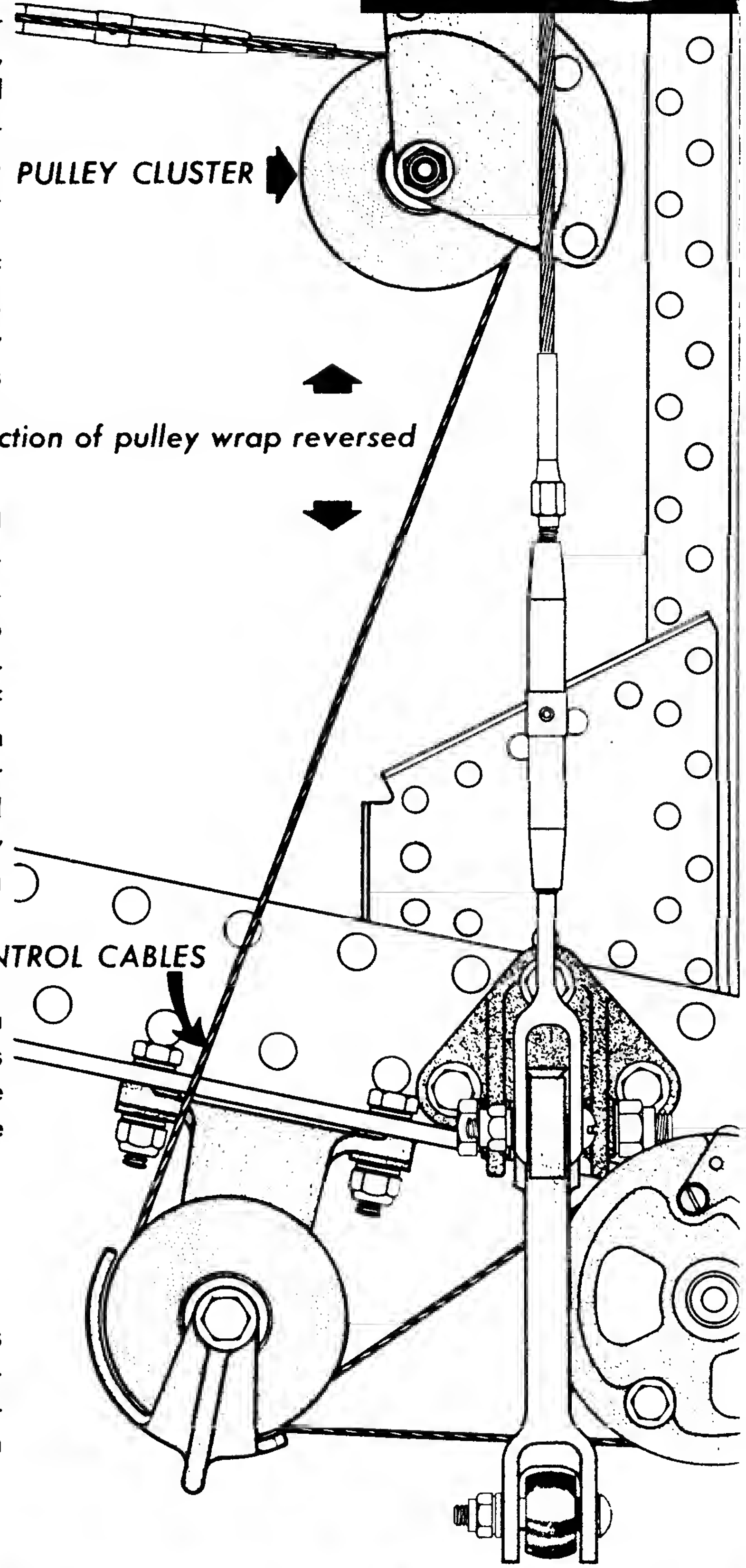
design notes

FUEL SYSTEM —
Fuel Tank Valve Controls

Cable Breakage Due to Excessive Wear

the Situation

A BROKEN CABLE was discovered in the fuel tank valve control system during preflight inspection, the second instance experienced by this airline. Cables in valve control systems of similar aircraft were also found to be so badly worn as to require replacing well ahead of the normal replacement period to be expected of this control system. In all cases, the cables were frayed to the extent of several broken strands in the area where the cables made 120 degree turns around each of two closely spaced pulleys. The cable that failed broke in this place.



the Hazard

The cable system was designed according to the company's design manual specifications on permissible wrap angle relative to pulley diameter. Nevertheless the cable broke prematurely. It is probable that the abrupt reversal of the wrap from one pulley to the other, resulting from the close spacing of the two pulleys, put the outer strands of the cable under extreme strain. This caused the fine wires to bend back and forth sharply as they passed over one pulley and on to the other, resulting in eventual failure of the strands.

the Fix

Revision of design manual data pertaining to cable installations is indicated not only in the above instance but wherever premature cable wear is experienced.

PRECEPT

The structure and its components should be designed to provide optimum reliability during its specified time of operation under given environmental conditions.

Ref: DESIGN NOTES, Bulletins 52-4, 52-7, and 54-3

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LANDING GEAR—
Main, Torque Tube

design notes

Dissimilar Materials – Corrosion

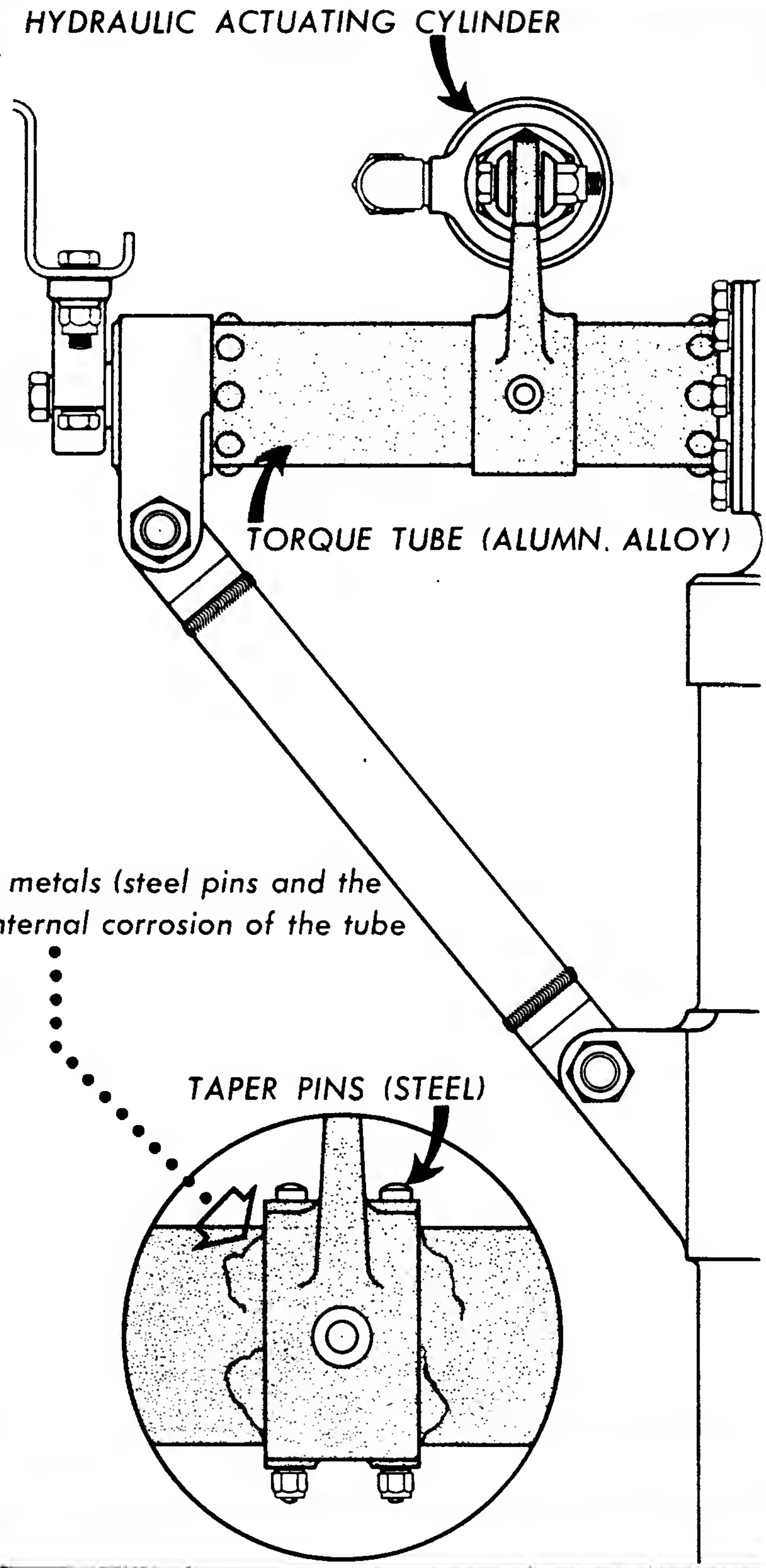
the Situation

A main landing gear of an amphibian aircraft collapsed on landing. Considerable damage to the structure resulted, and the crew sustained minor injuries from being severely shaken up. Cause of the accident was failure of a torque tube in the retraction mechanism.

the Hazard

The failed torque tube, made of an aluminum alloy, was attached to the retraction actuating lever by steel taper pins. Constant exposure to the corroding effects of sea water produced electrolysis between the dissimilar metals (aluminum and steel) inside the tube where it escaped notice. The internal corrosion progressed to where the tube was weakened sufficiently to fail when landing loads were applied.

Examination of the opposite gear also revealed internal corrosion which had progressed to where failure was imminent.



Electrolytic action of dissimilar metals (steel pins and the aluminum alloy tube) caused internal corrosion of the tube

the Fix

The aluminum alloy tubes were replaced by welded assemblies consisting of steel tubes, actuating levers, and shock absorber strut attachment flanges.

PRECEPT

The structure and its components should be designed to provide optimum reliability during its specified time of operation under given environmental conditions.

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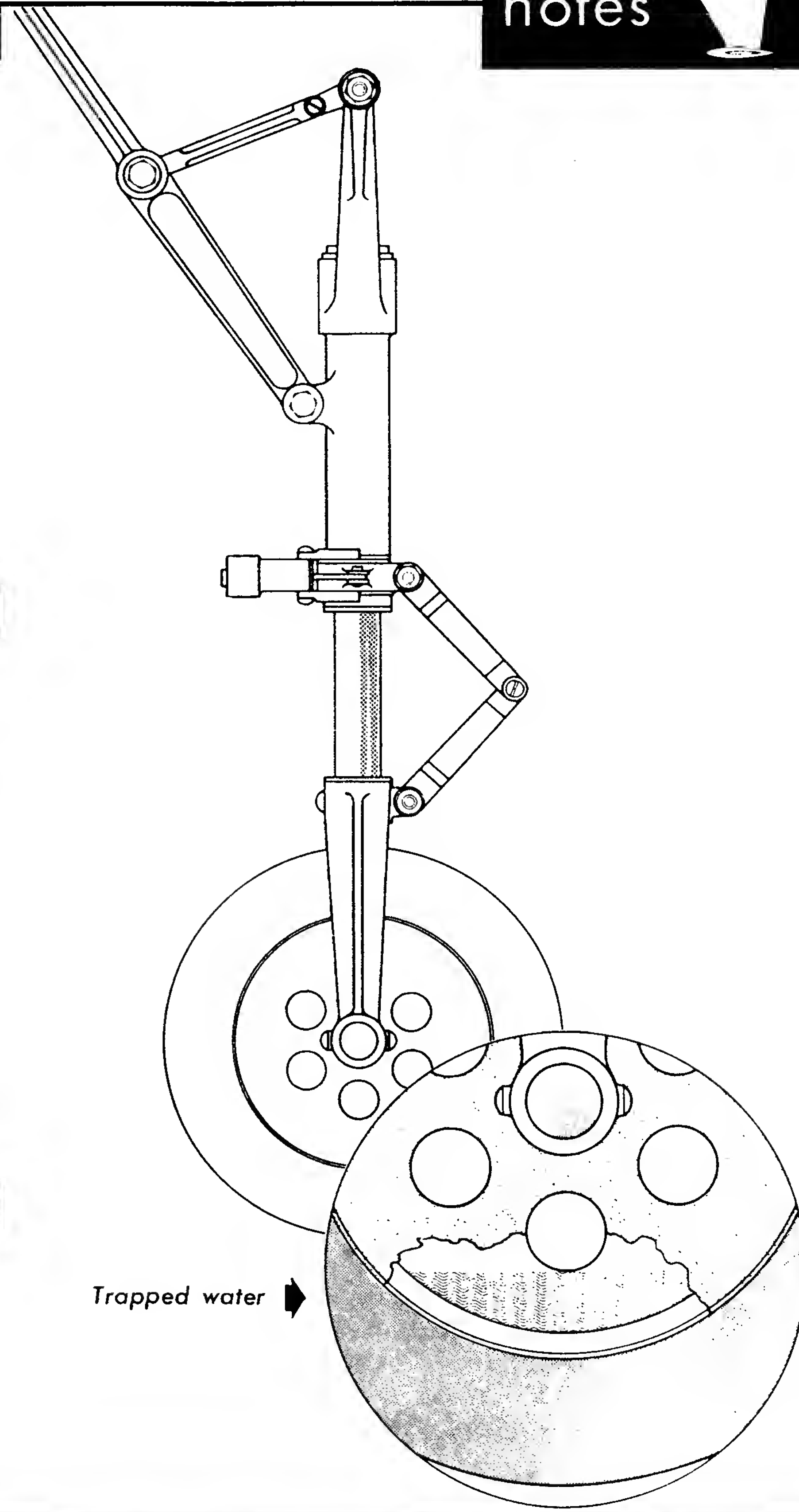
Nose Wheel Design Entrapped Water

The SITUATION

A landing gear nose wheel was designed with a built-in hazard. Because there were no drain holes, a quart of water could accumulate inside the wheel and freeze, or cause unnoticed corrosion.



The HAZARD

Ordinarily, aircraft would not experience difficulty in taking off with water entrapped in the wheel. But water frozen into a two-pound chunk of ice would unbalance a nose wheel enough to cause it to shimmy dangerously during high speed landing or takeoff. To cite an incident: Uncontrollable shimmy of an interceptor type aircraft occurred during the high speed landing roll. The severe nose wheel vibration in the horizontal plane had actuated the following circuit breakers: all four fuel boost pump circuits were off; ILS (instrument landing system), gun sight, and the right hand leading edge flap circuits had been deactivated.*

The FIX

Eight drain holes, 0.125 in. dia. were drilled close to the wheel's outer edge.

* Ref: Directorate of Flight and Missile Safety Research, USAF, Norton AFB, Calif.

STABILIZER CONTROLS—
Stick Pos. Transmitter Linkage

design notes

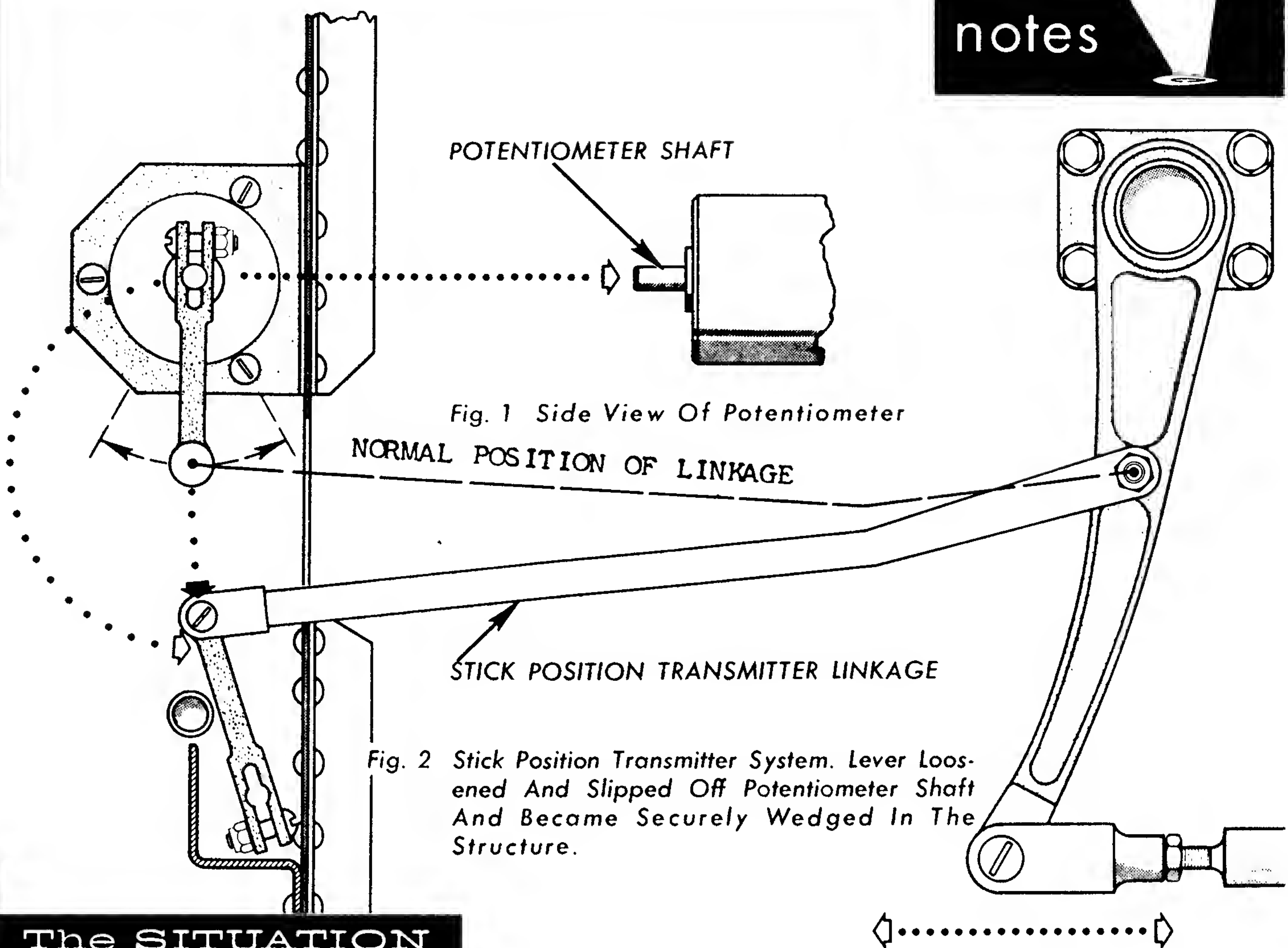


Fig. 1 Side View Of Potentiometer

Fig. 2 Stick Position Transmitter System. Lever Loosened And Slipped Off Potentiometer Shaft And Became Securely Wedged In The Structure.

The SITUATION

DISCOVERING HIS RADIO HAD FAILED, just as the jet aircraft turned into the final leg of a ground-controlled approach, the pilot applied power for a go-around. Attempting to level out from a slightly nose-down attitude, the fore and aft movement of the control stick jammed and could not be moved. Attempts to regain control by trimming were unsuccessful and the aircraft struck the ground short of the overrun, shearing off the landing gear. In sliding 1800 feet, further structural damage was done but the pilot fortunately survived the accident without injury.*

The HAZARD

Loss of stick control was caused by a lever slipping off the stick position transmitter and the linkage becoming securely wedged in the structure. This stick position transmitter controls the electro-hydraulic power system which actuates the stabilizer. When the linkage disconnected, the pilot lost all means for actuating the power source of stabilizer movement.

The stick position transmitter, a potentiometer, had a small size shaft (1/4 in. dia.), which lacked reliable means for attaching anything such as a lever to it. The shaft being perfectly round and smooth, instead of having serrations or flat surfaces, friction alone was mistakenly relied upon to hold the lever in place. Eventually, continued vibration caused the lever to loosen and slip away from the shaft resulting in a costly accident.

COMMENT

In lieu of obtaining other potentiometers whose shafts are designed in such a manner as to assure reliability of attachment, a small hole was drilled in the shaft to receive a cotter pin to keep the lever from falling off. This proved only half safe: preflight inspections revealed instances in which cotter pins had not been installed. Also, the cotter pin would do nothing to prevent the lever from loosening (the initial event leading to the accident) and would not correct the basic design deficiency of the potentiometer: the small diameter, smooth shaft. This design defect is common to many types of small, low-torque devices.

*Ref: DIRECTORATE OF FLIGHT AND MISSILE SAFETY RESEARCH, OFFICE OF THE INSPECTOR GENERAL, USAF, NORTON AFB, CALIFORNIA.

ENGINE, TURBINE—
Afterburner Fuel Lines

design notes

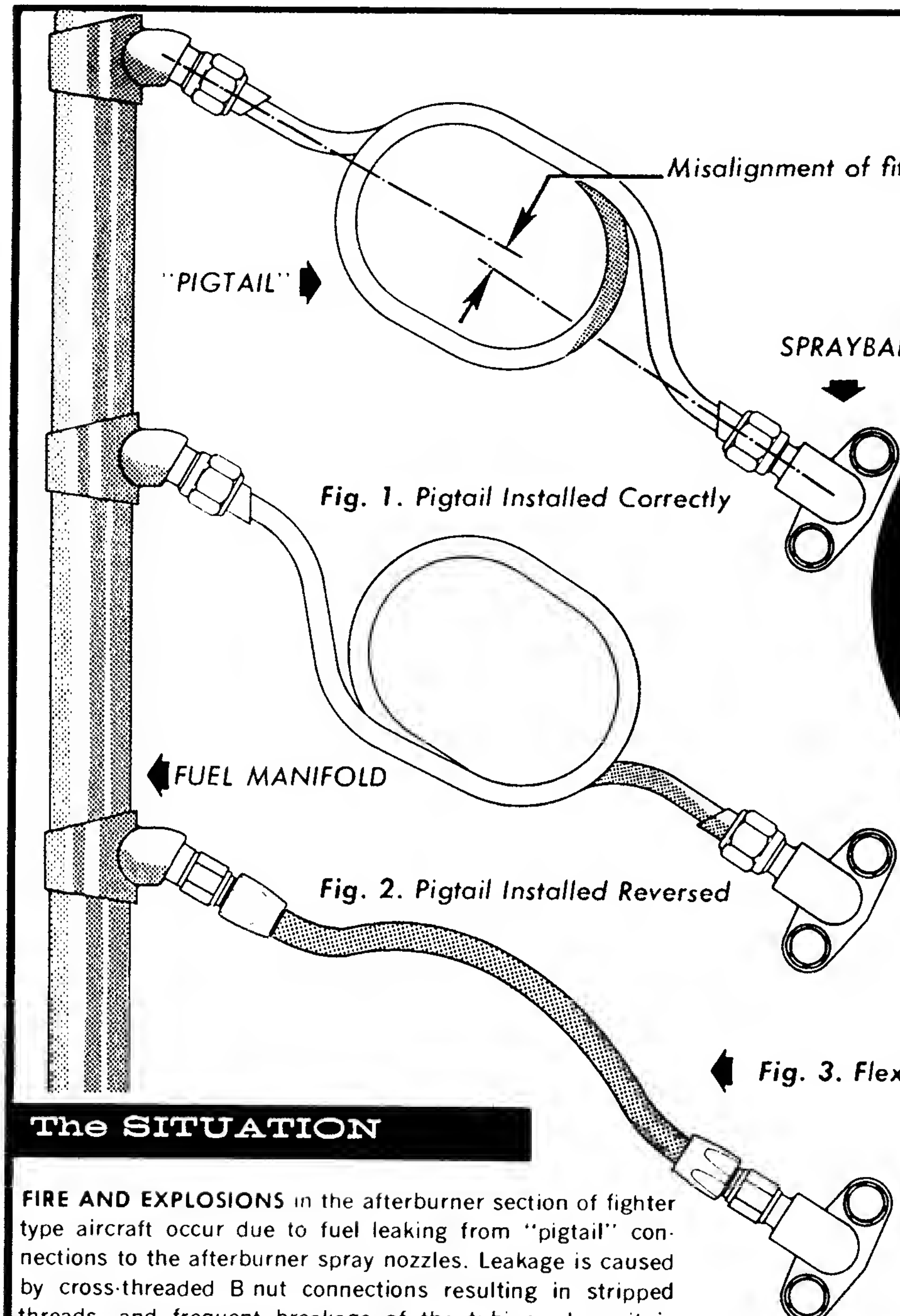


Fig. 1. Pigtail Installed Correctly

Fig. 2. Pigtail Installed Reversed

Fig. 3. Flexible Metal Hose Connection

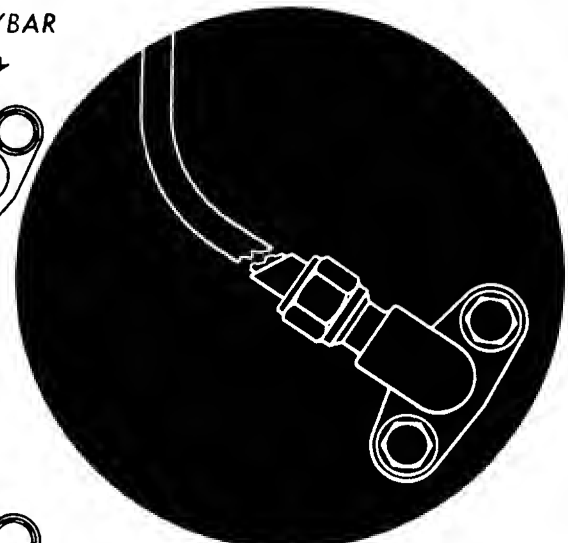


Fig. 4. Typical Break In Fuel Line

The SITUATION

FIRE AND EXPLOSIONS in the afterburner section of fighter type aircraft occur due to fuel leaking from "pigtail" connections to the afterburner spray nozzles. Leakage is caused by cross-threaded B nut connections resulting in stripped threads, and frequent breakage of the tubing where it is silver soldered to connector ferrules.*

The HAZARD

BOTH CROSS THREADING OF THE B-NUTS and broken tubing of the pigtail connectors result from the existing misalignment of the spray bar and fuel manifold connections. They are just enough out of line to escape the notice of a mechanic not thoroughly familiar with the situation, and permit the pigtails to be installed in reverse. When this is done, threads are likely to be stripped and the soldered joints crack open due to the excessive bending stress on the joint caused by forcing the tube into place. Each engine has 24 pigtails; 48 chances of a leaky connection.

COMMENT

MUCH OF THE COSTLY DIFFICULTY would disappear if the spray bar and manifold connections were designed to be in line. The pigtails could then be made symmetrical and thereby installed easily without the danger of cross threading.

It is not clear why the existing condition could not be alleviated by substituting a flexible metal hose for the present rigid pigtail.

*Ref· DIRECTORATE OF FLIGHT SAFETY, DEPUTY INSPECTOR GENERAL FOR SAFETY, USAF, NORTON AFB, CALIFORNIA.

LANDING GEAR—
Wheel Assem; Main

design notes

The SITUATION

SERIOUS ACCIDENTS are being caused by the failure of landing gear wheels. Many such failures are the result of metallic fatigue starting in small cracks in the wheel forgings and spreading until the material is weakened to the point of rupture unless they are discovered in time.

Another type of failure, also the result of fatigue, has appeared recently in the form of fractured wheel tie-bolt heads. Its sudden appearance in jet operations probably is due to increased loads on the wheels and severe vibration resulting from high takeoff and landing speeds.*

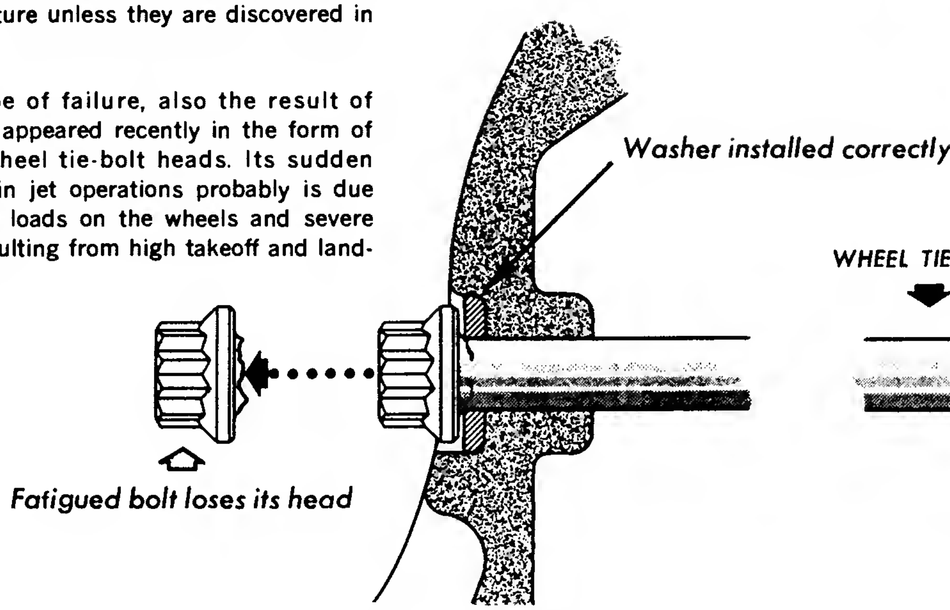


Fig. 1 Fatigue Starts In Nicked Radius Of Bolt

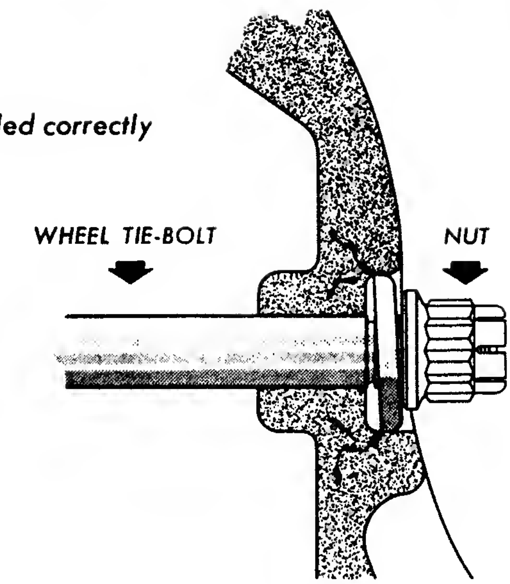


Fig. 2 Improperly Installed Washer

Nearly four years ago, a Design Note was issued describing the cause of wheel failures and suggesting a remedy to prevent fatigue cracks from starting because of washers being improperly installed. It is evident that the remedy was not universally applied as accidents due to this cause continue to occur.

The HAZARD

THE WASHERS UNDER THE BOLT HEAD AND NUT are made of thick steel. Ordinarily, one edge is rounded to correspond to the radius of the spot facing surrounding the wheel's tie-bolt holes (the original Design Note advocated rounding both edges of the washers). When properly installed, these washers fit the spot facing radius without damaging the wheel's softer metal. If, however, the sharp edge is jammed into the indentation (Fig. 2), fatigue cracks are likely to start and, because they are hidden under the washers, remain undetected. Also, washers improperly installed under the bolt head, or washers that do not have the edges of the hole relieved (Fig. 1), cause frequent bolt failures. The sharp edge jammed against the bolt head radius nicks the material causing fatigue cracks to start.

*Ref: DIRECTORATE OF FLIGHT SAFETY, DEPUTY INSPECTOR GENERAL FOR SAFETY, USAF HQ, NORTON AFB, CALIFORNIA

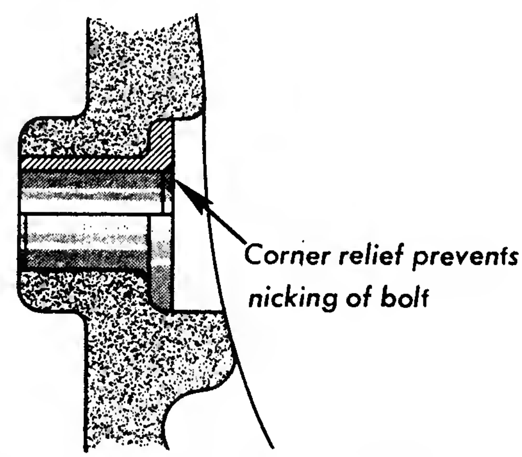


Fig. 3 Steel Insert Eliminates Washers

The FIX

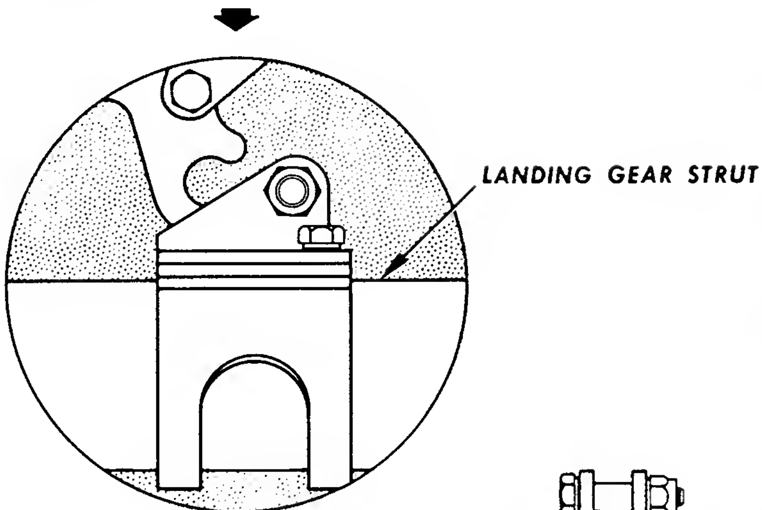
A POSITIVE FIX for both hazardous situations is shown in Fig. 3. The pressed-in steel bushing does away with many loose parts (washers) and prevents operation of Murphy's Law.† Relieving the hole in the bushing eliminates the cause of bolt head failure.

†MURPHY'S LAW: "If an aircraft part can be installed incorrectly, someone will install it that way."

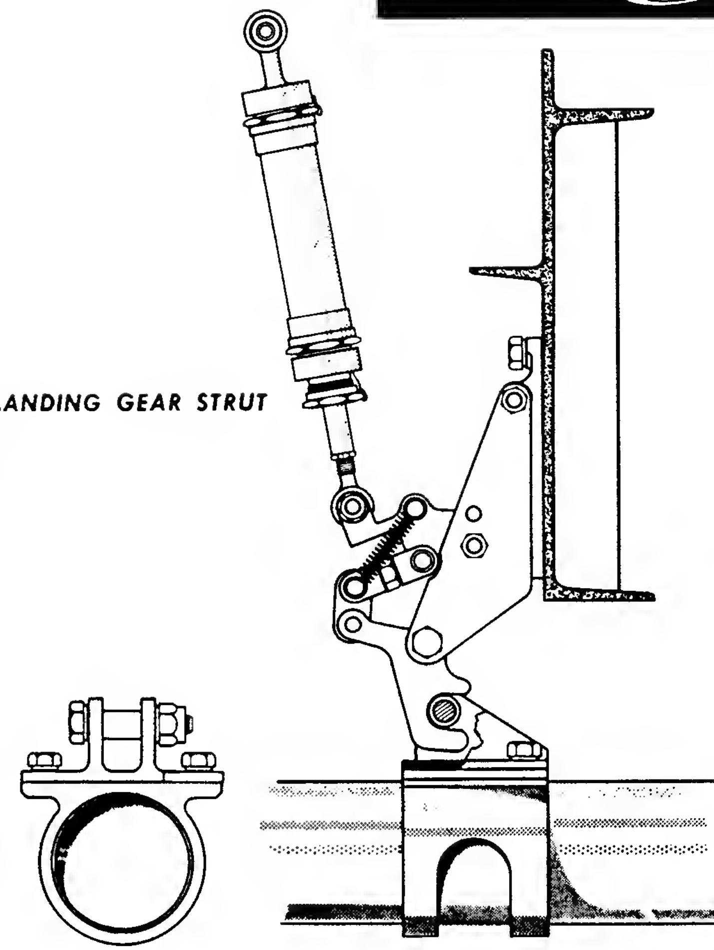
LANDING GEAR — Uplock Actuating System

The SITUATION

A LANDING GEAR UPLOCK HOOK failed to engage the latch pin on the strut when the gear was retracted. The reason for the malfunction was discovered in the latch pin fitting; it had been attached to the strut in an upside down position which placed the pin too far from the hook for the two to engage.



This is a unique situation: The designer, in considering the possibility of such an event, purposely designed both the fitting and the strut mounting pad to have 3-hole matching bolt patterns. This arrangement would have prevented wrong assembly.



END VIEW

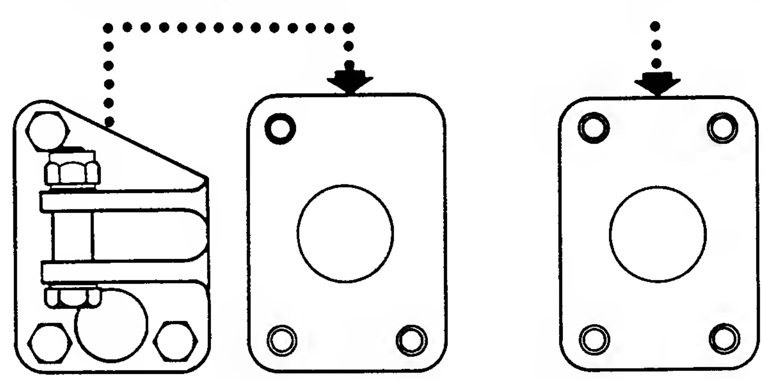
Landing Gear Uplock

The HAZARD

SOMEWHERE IN THE MANUFACTURE OF THE PARTS (probably in the design of the tooling), the airframe designer's good intentions were defeated; the mounting pad on the strut was made with four holes arranged symmetrically which allowed the fitting to be attached either way in conformance with Murphy's Law.†

Apparently someone assumed the mounting pad should have four holes instead of an odd number and proceeded to make the hole pattern symmetrical without consulting the design engineer.

Assembled one way only *Wrong assembly possible*



LATCH PIN FITTING FITTING ATTACHMENT PAD

†MURPHY'S LAW: "If an aircraft part can be installed incorrectly, someone will install it that way."

ELECTRICAL EQUIPMENT—
Design Details

design notes

The SITUATION

ON SEVERAL OCCASIONS, fires occurring in aircraft electrical systems were the result of thru-leads grounding out. The intense heat from the circuits grounding out, and connections loosening because of poor equipment design, ignited combustible materials besides causing wiring insulation to smolder. There have been several instances of smoke and fumes from burning insulation getting into flight compartments and passenger accommodations by way of the air conditioning systems.

Most of the trouble lies in bushings which fail to prevent live terminals from grounding out (see Fig. 2). This, coupled with the absence of a nut and lockwasher to hold the studs in place after the circuit lead is disconnected, presents an additional hazard.

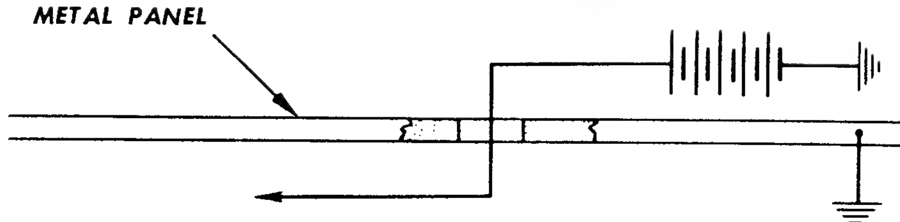


Fig. 1. THE PROBLEM: To conduct current to opposite side of the metal plate without danger of grounding.

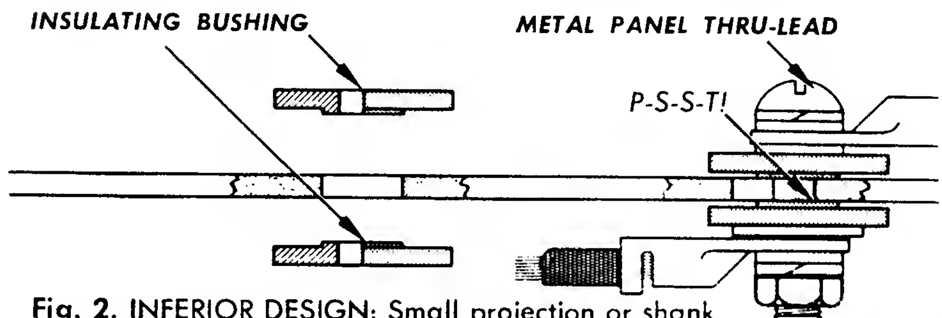


Fig. 2. INFERIOR DESIGN: Small projection or shank allows bushing to easily slip out of hole in mounting plate. Also, note omission of the retaining nut "A" and lockwasher shown in Fig. 3.

The FIX

DESIGNED FOR SAFETY, the thru-lead bushings shown in Figs. 3 and 4 have long shanks to prevent them from slipping out of the holes in the metal panels. Insulating washers slipped over the shank of the bushings completely isolate the current carrying portion of the terminals from the grounded metal panel.

A thru-lead using the bushing-washer combination shown in Fig. 4 is designed for use in bulkheads or partitions.

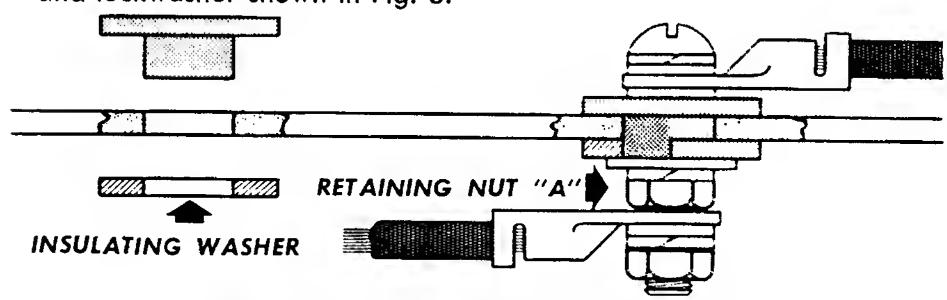


Fig. 3. SUPERIOR DESIGN: Bushing's long shank prevents stud from shifting out of place.

COMMENT

TEN YEARS HAVE PASSED since the original Design Note on this subject was issued. Since the identical design deficiencies continue to show up in electrical equipment of the latest jet aircraft and missiles, it is evident that these small but important details are being overlooked either through carelessness in design or lack of "know-how."

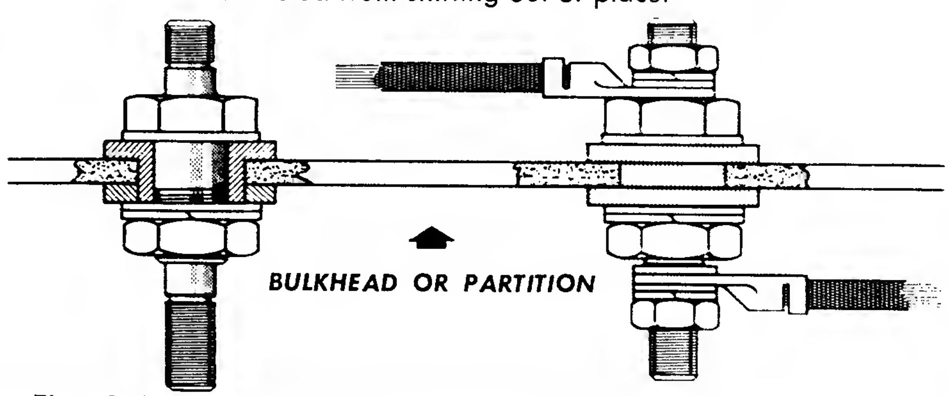


Fig. 4. BULKHEAD THRU-LEAD: Circuits on either side can be removed without disturbing opposite connections.

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